The Decadal Variability of Extreme European Heat and Drought Stress

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The likelihood of succeeding, year-after-year single and compound heat and drought stress is increasing as the planet warms. We investigate these changes over Europe using an excess-stress framework that combines the effects of both intensity and persistency of all extreme events within a season. We expand on this framework, originally based on Excess Heat from maximum temperatures, to cover three additional excess metrics that reflecting heat and drought stress: Humid Heat, Night Heat, and Rain Deficit. In addition, we also assess combinations of these single metrics reflecting different compound heat and drought stress types: Compound Heat Stress, Compound Heat and Drought, and Drought-Rain Volatility. Furthermore, we assess the likelihood of reaching end-of-century excess heat and drought stress levels already in the near-term future due to decadal climate variability; and how different phases of the Atlantic Multidecadal Variability (AMV), a prominent driver of the decadal variability over Europe, influence single and compound heat and drought stress extremes.

To do this, we use the 100-member Max Planck Institute Grand Ensemble (MPI-GE), currently the largest existing initial-condition ensemble of a comprehensive, fully-coupled Earth System Model. Large ensemble size, highly relevant for univariate events, it is even more important for multivariate events and temporally succeeding compound events. The precise sampling of internal variability provided by the large ensemble size in MPI-GE is crucial to capture the even rarer chance of experiencing extreme conditions in more than one variable simultaneously, or the conditional probabilities of extreme conditions occurring again after an already extreme year.

Our findings indicate that succeeding extremes increase dramatically over Europe, to almost all years being extreme for Excess Heat and Night Heat by the end of the century, and to 80% for Humid Heat. Night Heat exhibits the most marked and consistent increase, highlighting lack of nighttime cooling as the most persistent form of heat stress over Europe. Chances of a whole decade of year-after-year extreme heat go from virtually impossible to 10-30% in just the next two decades; and chances of three to five consecutive years of succeeding compound extremes goes from virtually zero to roughly 10-20%. The decadal variability in these heat and drought excess metrics becomes so large that it can bring end-of-century conditions upon Europe already in the near-term future. Starting in 2040, there is a 10% chance of exceeding average end-of-century levels in all heat metrics; chance that exceeds 25% by 2060. This likelihood of reaching end-of-century conditions is highly influenced by different phases of the AMV. Positive AMV phases lead to over 100% higher chances of reaching heat stress conditions typical of the end-of-century average decade already in the next few decades.